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# Whose Time Is It? Understanding Clock-time Pacing and Event-time Pacing in Complex Innovations

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**ABSTRACT** Time pacing, which refers to the regulation of intensity and direction of people's attention and effort, is central to innovation management. However, in a study of complex product innovation in pharmaceuticals, we find that time pacing is a major source of conflict between managers and scientists over innovation management. Our analysis of this tension reveals that two very different forms of time pacing operate in this complex innovation. Clock-time pacing, which gauges progress by the predictable passage of clock time, is used by strategic managers to reduce unnecessary exploration, focus on necessary questions, and speed up the execution of steps. Event-time pacing, which gauges progress by the unpredictable achievement of learning events, is used by the scientists to develop a deep understanding of how a drug might behave in the body against a disease, to focus on learning by asking many questions, and to integrate emergent results into plausible patterns. We identify four dimensions that differentiate clock-time pacing from event-time pacing, which drive the tension between the two. We summarize negative effects that this tension can have on innovation if left unaddressed, and then suggest ways to integrate clock-time pacing with event-time pacing. We also discuss implications for Chinese management.

**KEYWORDS** clock time, complexity, event time, innovation, pharmaceuticals, time pacing

## 谁更胜一筹？在复杂创新中理解钟表时间节奏和时间事件节奏

**摘要**

时间节奏，即组织对其成员应在何方向、多大程度付出精力的规范，对于创新管理至关重要。然而，在本文对制药业的复杂产品创新研究中，我们发现时间节奏是管理者和科学家在创新管理中的一个主要冲突来源。对这种冲突的分析揭示出，在复杂创新中存在两种形式截然不同的时间节奏。钟表时间节奏以可预测的客观钟表时间来衡量事件进程，战略管理者采用此种时间节奏来减少不必要的探索，将注意力集中在必要的问题上，并加速执行进程。事件时间节奏以不可预测的学习成果来衡量事件进程，科学家采用此种时间节奏来建立对于药物作用循序渐进的深刻理解，通过提出问题将注意力集中在学习过程，并将意外结果整合进可能合理的假设模式中。我们定义了四个区分钟表时间节奏和事件时间节奏的维度，也正是这四个维度造成了两种节奏的冲突。最后，本文总结了忽视这种冲突对于创新所可能产生的负面影响，并对如何协调融合钟表时间节奏和事件时间节奏给出了建议。同时，我们讨论了课题对于中国管理的意义。

**关键词**：钟表时间，复杂，事件时间，创新，制药业，时间节奏

## INTRODUCTION

Time pacing has become a central component of innovation management (Barkema, Baum, & Mannix, 2002; Brown & Eisenhardt, 1997). Defined as the regulation of the intensity and direction of people's attention and effort, time pacing helps coordinate the many activities of innovation and provides milestones to gauge progress (Gersick, 1994). Time pacing also generates strategic momentum, enabling organizations to more efficiently coordinate innovation projects and allocate resources to innovation (Turner, Mitchell, & Bettis, 2012). However, in a study of complex product innovation in the pharmaceutical industry, we find that time pacing is a major source of conflict between managers and scientists. Strategic managers face clock-based pressures, such as fiscal year reports and quarterly sales cycles, so they pace innovation work with clocks and calendars, and gauge progress against linear time, by whether or not they meet schedules. Scientists, however, face event-based pressures; they must learn enough about the patterns of interactions among a disease, compounds, and the rest of the human body to evaluate drug possibilities and choose the next course of action. Scientists pace innovation work with these learning events, and gauge progress against nonlinear time, by the emergence of unpredictable learning events that cannot be clocked or scheduled. As a result of this tension over time pacing, managers and scientists do not effectively coordinate the many activities of drug discovery or properly gauge progress.

The literature on time and organizing supports this dichotomy, and distinguishes between *chronos* or clock time (the serial time of succession measured by the chronometer), and *kairos* or event time (the subjective, living time of intention, or people's sense that the time is right; see Garud, Gehman, & Kumaraswamy, 2011; Orlikowski & Yates, 2002). Research also suggests that innovation management should combine clock-time pacing and event-time pacing, since each addresses different facets and levels of innovation (Garud et al., 2011; Gersick, 1994). However, research does not explore the tension between these different forms of time pacing deeply enough to reveal the underlying causes of tension, and so cannot provide much insight into why the tension exists and how to combine the two forms of pacing effectively. Therefore, we address three research questions. What differentiates clock-time pacing from event-time pacing, and causes a tension between them? How does the tension between managers and scientists over time pacing negatively affect innovation? What are some ways to overcome these negative effects and combine the two perspectives on time pacing?

We use grounded theory building to develop a fine-grained analysis of time pacing for complex product innovation in pharmaceuticals. We define clock-time pacing as that which uses precise measures of clocks and calendars to regulate attention and effort, coordinate activities, and gauge progress. We define event-time pacing as that which uses unpredictable occurrences of learning events to regulate attention and effort, coordinate activities, and gauge progress. We find



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that learning events are not simple or discrete incidents in which occurrence and hence timing are unambiguous. Rather, learning events emerge over time and are iteratively revisited as more is learned. Both forms of time pacing are temporal – about time – because both mark durations and map out future trajectories by indicating when activities start or stop. But clock-time pacing marks beginnings and ends of activities with clocks and calendars, whereas event-time pacing marks beginnings and ends of activities with learning events, the timing of which is unpredictable.

Our study contributes to the literature on time and innovation in three ways. First, by differentiating clock-time pacing from event-time pacing, we expand the ways in which time pacing helps to manage innovation. We extend existing theory about two forms of time pacing (e.g., Garud et al., 2011; Orlikowski & Yates, 2002) by explaining the unique roles each plays in complex innovation. We show that event-time pacing coordinates activities that cannot be organized by clock-time pacing, and that learning events are a crucial motivator of meaningful progress for complex innovation. Second, we explore this critical tension between managers and scientists over time pacing at a sufficient depth to understand its causes. We find that this tension arises from divergent milestones to gauge progress, which leads each group to coordinate different subsets of innovation activities in opposing ways. Moreover, the dominance of clock-time pacing stifles the effective use of event-time pacing. As a result, managers and scientists work at cross purposes, even though all activities are mutually supportive. These differences hinder innovation by fragmenting work, biasing assessments of progress, and reducing the alternatives and consequences that are considered. Third, while more speculative, we suggest ways of combining both kinds of time pacing so that innovators can encompass more possibilities as they search and learn, and explore them more productively.

## THEORETICAL BACKGROUND: INNOVATION AND TIME PACING

To frame our analysis of the tension between managers and scientists over time pacing, we summarize the well-established literature on qualitatively different kinds of time (Bluedorn, 2002; Clark, 1985; Zerubavel, 1981), and how these ideas have been applied to innovation (Brown & Eisenhardt, 1997; Garud et al., 2011). Time has diverse meanings because it is subjective and socially constructed, but scholars suggest that two categories capture these diverse approaches to time: *chronos* or clock time, and *kairos* or event time.

### Clock Time versus Event Time

Clock time or *chronos* is '. . . the chronological serial time of succession . . . time measured by the chronometer not by purpose' (Jacques, 1982: 14–15). Clock time is associated with a mechanical view of the world and suggests a rational and



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precise ordering of activities because clock time is quantitative, is seen as objective and universal, and seems free from contingent events (Orlikowski & Yates, 2002). Bluedorn (2002) argues that clock time is taken for granted as the 'real' time, especially in Western cultures, so people may equate 'time' with clocks and calendars, and treat trajectories of activities that cannot be precisely scheduled as if they are somehow outside of time.

Clark (1985), Bluedorn (2002), and others argue that clock time continues to dominate industrial societies. Studies of non-industrialized peoples, including histories of now industrialized societies prior to the existence of clocks, show that people always could 'tell time', but without clocks relied on events that cannot be precisely measured or predicted (e.g., when will the floods come this year; when is it time to marry, see Clark, 1985). Despite the tendency to privilege clock time, most people in industrial societies also rely on other systems of time to anticipate future events, such as biographical time (e.g., time to start a family), career time (time for a career change), or agricultural time (time to plant). Event-based time systems like these reflect *kairos*. *Kairos* is named after the Greek god of opportunity and refers to 'the human and living time of intentions and goals . . . the time not of measurement but of human activity, of opportunity' (Jacques, 1982: 14–15). Events are not fixed or regular but are more dynamic, flow unevenly, and contain varying levels of contingency. Event time paces activities by a sense of readiness (*kairos*), not by dates.

## Defining Innovation and Complex Innovation

In this study the focus is on product innovation, which concerns the creation, combination, and recombination of knowledge about elements that comprise the product, such as technologies, manufacturing, user needs, and basic science, how to integrate these elements into a novel pattern, and how to bring the new pattern into existence. Product innovation, therefore, requires considerable coordination among specialties within and across organizations so people can integrate what they know and do to design, develop, and launch new products (Dougherty, 1992, 2001). Innovative organizations generate streams of new products at once rather than one product at a time (Tushman & O'Reilly, 1997), so they also enable multi-functional coordination across a variety of projects, and develop technologies and other capabilities to support new opportunities over time. Coordinating all these activities at all these levels is complex, and surveys of CEOs show that organizations continue to struggle with these challenges (e.g., Mitchell, Ray, & van Ark, 2012).

Our study centers on the discovery of new drugs for unmet medical needs, which is a complex innovation process. Complexity exacerbates these challenges of coordination, because new drugs take many years to develop (new drugs now average thirteen years, versus two years for incremental products), are much more uncer-



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tain (there is a 95 percent failure rate for new drugs, versus less than 40 percent for products in general), cost a great deal (new drugs average more than $1 billion), and involve many new specialties that are dispersed across an ecology of public and private agents (see, Collins, 2011 on pharmaceuticals, Adams, 2004 on innovations in general). Drug discovery involves identifying a protein 'target' that is part of a disease, building a chemical compound that binds to that target to reduce the disease, and assuring that the compound will not harm other biological systems in the body. Unmet medical needs, such as cancers or Alzheimer's, are complex diseases that involve a number of different genes that express a variety of possible targets over time. How these genes work differs across the human population (Singer, 2009). These diseases also have multiple cell pathways, so it is challenging to find one protein in one pathway that can be 'drugged', and if drugged will reduce the disease without compensating other pathways. While enormous gains have been made in medicine, much more is unknown than known about human biology, so scientists cannot easily determine whether or not a compound will affect other systems in the body (Burns, 2005).

## Clock-time Pacing and Innovation

Many researchers focus on clock-time pacing. For example, Gersick (1989) finds that student teams punctuate a school term project at its midpoint, and use this clock-time milestone to reflect on progress and re-evaluate tasks for the remainder of the time. In a case study of a five-year-old venture (Gersick, 1994), a manager used a variety of clock-time schedules, such as the midpoint of the fiscal year, to get the venture ready for liquidity (e.g., being acquired). These scheduled milestones enabled him to persevere with a strategy, but also re-evaluate it and perhaps choose a new path. Brown and Eisenhardt (1997) also emphasize clock-time pacing in their case study of software innovation. Like Gersick, they show that clock-time pacing plays a vital strategic role in managing innovation. In innovative software businesses, change is triggered by the passage of clock time: a business launches new products every six months regardless of competitive actions, enters new markets every third quarter rather than when an opportunity appears, and starts another product platform every twenty-four months rather than when technologies evolve. Brown and Eisenhardt (1997) argue that a rhythmic pattern of change enables people to adjust the intensity of their efforts, creates a predictability that makes people feel in control, and gives people greater confidence. Turner et al. (2012) support this case study with a large sample study of software firms. They argue that introducing new products at set points in time builds a temporal consistency that enhances efficiency and reduces coordination challenges.

While clock-time pacing has notable benefits, it also has limitations. First, when it is allowed to dominate, clock-time pacing makes near future deadlines most salient (Clark, 1985), and shifts attention to exploitation, which undermines



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exploratory learning (Orlikowski & Yates, 2002). Second, managers may use clock-time pacing mindlessly, generating faulty rhythms that are based on inappropriate time periods (Brown & Eisenhardt, 1997). Third, it is unclear how clock-time pacing can be applied to complex innovation, because most studies focus on incremental innovations that take months, not years, and use activities that are understood well enough to predict how long they will take. For example, stopping every six months (cf. Gersick, 1994) to evaluate strategy is a sensible idea, but it is difficult to determine what to evaluate at six month intervals when complex innovations take thirteen years and do not develop in a linear fashion. While rhythm and temporal consistency generated by clock-time pacing are desirable, pharmaceutical managers cannot know when or even if projects will be ready for market, making it difficult to generate rhythm and consistency.

## Event-time Pacing and Innovation

Some scholars suggest that innovators can use event-time pacing in addition to clock-time pacing to help orchestrate complex innovation. According to Bluedorn (2002), event temporal structures produce a deeper time perspective so people look further into the future, draw more on experience, and spot patterns that are invisible over a shorter time span. Gersick (1994) finds that a venture capitalist used the occurrence of events that cannot be timed precisely to signal when actions should be taken or corrections made (e.g., when sales reach a certain level). Orlikowski and Yates (2002) illustrate how a leader in a software community used drafts of a manual for a new software language as endogenous events to initiate open-ended discussions of perceived gaps and problems. Another study finds that events such as research breakthroughs and military contracts triggered change to keep people persevering with complex innovations, such as the first fibre optics or full body CT scanner (Lynn, Morone, & Paulson, 1996). Garud et al. (2011) find that 3M strategies enable the combination of *chronos*, through incremental innovation, and *kairos*, through long term development of new technology platforms that create new capabilities.

Event-time pacing has limitations as well. First, rather than focusing on the near term, event-time pacing has no deadlines, so people may stick to an unproductive course of action for too long (Gersick, 1994). Second, what constitutes appropriate use of event-time pacing remains much less developed, since event-time pacing for innovation has not been studied in depth. According to Orlikowski and Yates (2002), event time is qualitative time; it is heterogeneous, discontinuous, and not equivalent when different time periods are compared. Such a broad set of properties suggests that almost anything goes, and indeed scholars use very different types of occurrences to represent events. Third, even though event-time pacing may be used, it is unclear how managers and innovators can apply it to complex innovation. Scholars point out that a tension exists between the two forms of time



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pacing (e.g., Garud et al., 2011; Gersick, 1994), but do not explain the root causes of the tension well enough to understand why it persists or how it can be overcome. When this tension is not managed effectively, research finds that the more familiar clock-time pacing dominates, with serious negative consequences. For example, Dubinskas (1988) finds that managers under time pressure from venture capitalists forced scientists to find shorter term projects that could generate quick revenues. This action limited the development of drugs that develop over more than a decade. Robertson (2008) finds that a long term clinical trial for a new drug was coordinated with clock time deadlines based on days and months, which reduced the ability to anticipate nonlinear events.

## METHOD

The purpose of this study is to develop a qualitative understanding of the tension between managers and scientists over time pacing. We use grounded theory (Dougherty, Su, & Chung, 2012; Strauss & Corbin, 1994) to characterize the essential qualities of clock-time pacing and event-time pacing, the tension between them, and how managers and scientists might deal with this tension.

### Data Collection

We interviewed 85 drug discovery scientists and managers about how they deal with the complexities of drug discovery. We study the drug discovery process in general, which is roughly similar for all companies (Ng, 2004; Pisano, 2006). We focus on the first six years of this thirteen year process, from initial idea development through 'proof of concept', to Phase II of clinical trials where drug effectiveness is tested on a small sample of people. Interviewees work in a variety of large, integrated pharmaceutical firms and small biotechnology firms, which enables us to look beyond particular organizational differences. Seventy-nine interviews were held at the work site and six were held by phone; seventy-four were machine recorded and transcribed, and eleven were hand recorded (some did not want to be machine recorded), and then transcribed. On average, each interview lasted an hour. To enhance our understanding of this context, we also interviewed fourteen industry consultants, attended multiple industry seminars, and reviewed a variety of books, articles, and reports about drug discovery as well as its challenges.

All but three of the eighty-five interviewees have PhDs and experience in drug discovery. Forty-three of the people interviewed are therapy scientists, who work directly on new drug development projects. These scientists have a variety of disciplinary backgrounds in medicinal chemistry, biochemistry, biology of various kinds, pharmacology, and physiology. Twenty-three are technology scientists who work in support of the discovery teams. Technology scientists work in specialty areas such as genomics, structural biology, or computational chemistry, and focus



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Table 1: People interviewed distinguished by work category and level[†]

| *Level in organization* | *Therapy scientists* | *Technology scientists* | *Strategic managers* | *Total # of interviews* |
|---|---|---|---|---|
| | *Work directly on new drug development projects* | *Support the discovery teams* | *Oversee R&D and business development* | |
| Vice President | 8 | 3 | 4 | 15 |
| Director | 18 | 9 | 8 | 35 |
| Team Leader | 8 | 4 | 7 | 19 |
| Team Member | 9 | 7 | 0 | 16 |
| Total | 43 | 23 | 19 | 85 |

*Notes:*

[†] We do not distinguish between people with and without PhDs because 82 of 85 have PhDs.

**Therapy scientists**: biologists, chemists, and other scientists working directly on teams focused on specific drug projects, and pre-clinical scientists who help teams prepare compounds for clinical trials; includes all science directors focused on the science.

**Technology scientists**: scientists in special units who create and screen materials, test and validate targets and compounds, and develop new kinds of targets and compounds (e.g., computational chemistry, high throughput screening, bioinformatics, structural biology).

**Business managers**: strategic managers and planners for R&D and how it connects with business units and other downstream assets, business developers, financial analysts.

on specific steps such as assessing the structure of proteins, building models of compounds, or screening for toxicity. Some technology scientists carry out predictable activities that can be clock-time paced, while some describe discovery work. The technology scientists provide more nuances on managing projects versus strategic resources, and more contrasts around perspectives on time pacing. In this article, we refer to the therapy scientists and the technology scientists as one group (i.e., the discovery scientists) because they both followed event-time pacing. Nineteen interviewees are strategic managers who oversee R&D and business development. Table 1 outlines the number of interviews by level for discovery scientists, technology scientists, and strategic managers.

The eighty-five interviews are in-depth or ethnographic (Spradley, 1979), and are unstructured to explore with people how they understand their everyday work practices around drug discovery, and how they deal with the challenges of complexity. We prepared for the interviews by studying books and articles about drug discovery so we would be familiar with terms, processes, and issues (e.g., Ng, 2004; Pisano, 2006). Interviewees were asked to describe what they do, how they approach work, the problems they encounter, and how they deal with these issues. We deliberately discussed the complexity of their work, and asked how they map work forward over time. To keep people grounded in the phenomenon and aid our understanding, we asked for concrete examples. To preserve confidentiality and reduce concerns over proprietary issues, we focused on the process of drug discovery in general, not on specific drugs they were working on at that time.



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These interviews comprise people's rationales for what they do, their insights on what works more and less effectively, and their stories of how drug discovery has evolved over time. They reflect people's interpretations, and since time pacing involves interpretive understandings, the interviews are a reasonable source of insight for this theory building study. The variety of people provides contrast around possible pacing mechanisms.

However, these data are limited in important ways. They do not include observations and do not capture processes as they unfold over time, so we infer time pacing perspectives from people's stories. We also cannot compare successful with failed drug discovery projects, since following thousands of projects over thirteen years to find the few successes was not a viable research option. Access limits constrained us to upper level people, so we have fewer insights from bench scientists and none from non-PhD technicians, as Table 1 indicates. How these factors might affect our findings remains an important empirical question.

## Data Analysis

Grounded theory building proceeds with 'coding' the data, which refers to the '(a)nalytic process through which data are fractured, conceptualized, and integrated to form a theory' (Corbin & Strauss, 1998: 3). To prepare for coding, we first reviewed the interviews overall, and then developed analysis files to focus on the differences between discovery scientists, strategic managers, and technology scientists. We prepared three data analysis files for each group by extracting comments from 30 of 85 interviews. Specifically, we pulled out discussions by discovery scientists about their own work on projects, about management, and about technology science. We also pulled out comments by managers about their own work, about discovery scientists, and about technology scientists, and the same for technology scientists. As we developed concepts by going back and forth over these files, we looked across the other fifty-five interviews to clarify the insights as appropriate. We also added full length interviews to our analyses to make sure we did not overlook other aspects of pacing in people's narratives. We worked in teams over many months, meeting weekly for several hours to discuss our findings, working separately to create additional analyses, and meeting again.

The first cycle of analysis suggested that discovery scientists and strategic managers differ over how they try to manage the future flow of drug discovery activities, and how they use time to gauge progress. We theorized that the underlying difference concerns time pacing, or different ways to regulate the intensity and direction of people's attention and effort over time. The second cycle of analysis delved into these disparate perspectives on time pacing to understand what differentiates them and how the tension between managers and scientists is created. We coded the data for how people pace work by looking at how they describe mapping forward, planning ahead, and anticipating future events in innovation.



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We iterated many times between our data and theory about clock-time pacing and event-time pacing to characterize the differences, as Bailyn (1977) describes. We defined project pacing events as learning events: learning enough about patterns of interactions among chemical compounds, diseases, and the rest of the human body to understand how a compound might behave in the body against a disease. Discovery scientists gauge progress by reaching these unpredictable learning events, while managers gauge progress by getting clear answers in a predictable period of clock time.

We identified four dimensions related to defining and achieving progress that differentiated the two groups over time pacing. These dimensions explain how each group focuses on different activities and objectives, and pulls in different directions. We then coded people's discussions about problems in discovery in general to identify three negative effects that the tension can have on innovation, if left unaddressed. Finally, we examined people's discussions of improvements in the drug discovery process to develop more speculative ideas for how to overcome the negative effects and combine clock-time pacing with event-time pacing.

## RESULTS

We find that the tension between strategic managers and drug discovery scientists is driven by divergent approaches for gauging progress that are generated by two different forms of time pacing. Each group understands milestones in drug discovery differently, and understands what constitutes progress differently. As a result of these disparate understandings, managers and scientists are in conflict over three pacing mechanisms concerned with making, assessing, and directing progress. Like all product innovation, drug discovery is comprised of milestones for progress, such as finding a good drug target, determining a compound that can bind to that target, and optimizing the compound. Because both clock-time pacing and event-time pacing anticipate these future drug discovery milestones and the activities needed to reach them, both are about time. But these divergent perspectives on time pacing map out the future of innovation projects in conflicting ways. To use a metaphor, each group marches to a different drummer, and also marches very differently.

Table 2 summarizes the four dimensions that we find to differentiate managers' clock-time pacing from discovery scientists' event-time pacing, in the far left column. As outlined in Table 2, managers understand the milestone events of drug discovery as finding discrete, clear answers to simple questions, such as 'is this a good drug target'? These answers are expected to arise readily from the efficient execution of tasks, so the milestone of finding a target occurs as a step at a particular point in time. In contrast, discovery scientists understand milestones as developing a deep understanding of how a drug might behave in the body against the disease, not as getting clear answers. Each learning event reflects deeper learning about the emerging pattern, and a sense of readiness (i.e., *kairos*) about that pattern. Discovery scientists



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Table 2. The tension between managers and scientists over time pacing

| *Dimensions that differentiate clock-time vs. event-time pacing* | *Managers' clock-time pacing: pacing by predictable passage of clock time* | *Scientists' event-time pacing: pacing by unpredictable learning events* |
|---|---|---|
| Milestones that mark progress, and how progress is understood | Clear answers to simple questions; progress is getting specific tasks completed within a measured period of time | Deep understanding of patterns of interactions among compound, disease, body; progress is achieving enough learning to decide plausibility |
| Pacing mechanisms for making progress | Reducing uncertainty, reducing number of questions that are asked, getting answers quickly | Learning, asking many questions, integrating insights into patterns |
| Pacing mechanisms for assessing progress | Objectively evaluating facts | Subjectively negotiating the meaning of learning events |
| Pacing mechanisms for directing progress | Linearly extending current work | Nonlinearly choosing next thrusts based on learning events |

anticipate these learning events, but they cannot predict when learning events will occur. So, for example, for scientists the milestone event of finding a good target emerges unpredictably over time, and does not occur in a single step at a specific point in time. Event-time pacing prompts scientists to understand progress as learning enough about a possible drug to decide if it is plausible. Scientists pace drug discovery with learning events, not with the passage of clock time.

The next three dimensions summarized in Table 2 concern the pacing mechanisms that are used by each group to make, assess, and direct progress. Managers make progress by focusing attention and effort on reducing uncertainty, honing in on a few questions, and getting answers quickly. Scientists make progress by engaging actively in learning, asking many questions, and integrating insights into patterns of interactions. Managers assess progress by objectively evaluating facts that are generated by these progress-making activities. Scientists assess progress by negotiating whether or not the emerging patterns seem plausible. Managers direct progress by choosing next steps that are already determined by the linear, step-by-step process, so future directions are an extension of current paths. Scientists direct progress in an iterative and non-linear manner, since next steps are discovered through learning events. Clock-time pacing concerns how many activities are executed within a given period of time, while event-time pacing concerns how much is learned in an anticipated but unpredictable period of time.

We present findings in three sections that address our three research questions. The first, most lengthy, section explores the tension between managers and scientists, and we contrast how managers versus scientists understand drug discovery milestones and what constitutes progress, and the three pacing mechanisms. The second section summarizes how the tension can harm innovation if it remains



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unaddressed. The third section suggests some ways to overcome the negative effects and combine the two perspectives on time pacing.

## Clock time versus Event Time Understandings of Milestones and Progress

*Getting answers vs. learning about emerging patterns.* We found very different senses of milestones in drug discovery and of progress in the work on which each group focuses. We begin with strategic managers' emphasis on getting clear answers as quickly as possible, and on the passage of clock time. Then we contrast the managers' clock-time pacing with the scientists' event-time pacing.

The *strategic managers'* perspective is that milestones in drug discovery concern getting answers to already identified questions:

> . . . we always have to answer the same questions along the way: is it safe, is it efficacious, does it have the right bio-pharmaceutics properties. But you want to pay less to get to the answer and that is where you use the modern technologies, to find ways to answer the question earlier and cheaper . . .

The milestones of determining safety, efficacy, and properties concern getting answers to well understood questions – 'we always have to answer the same questions . . .' They gauge progress by how quickly and cheaply they can get those answers. Another manager echoes this understanding of milestones as getting answers and progress as getting those answers as quickly:

> The challenge for [the scientists] is how can you answer the question with a greater certainty that you have gotten the right answer and how can you do it more cheaply and how can you do it faster?

Consistent with clock-time pacing, some managers focus on cycle time, which refers to reducing the time to develop and launch a new product. A manager at one large pharmaceutical firm thinks that this industry lags behind other industries on learning to reduce cycle times:

> . . . without a focus on reducing cycle times, which is basically looking at transformational ways to do things that we used to do in a certain way that can dramatically reduce time and cost, [our efforts to improve drug discovery] are incomplete . . . We are still going through what other industries in the past have gone through and successfully figured out. We just have not done it.

This manager emphasizes that 'having that pressure' of reduced cycle time is the primary way to improve drug discovery. In his mind, the passage of clock time substitutes for the occurrence of milestones, so clock time paces the intensity and direction of people's attention and effort.



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Managers are well aware of a tension with scientists over time pacing. For example, this manager explains that biotechnology companies are more productive because time pressure focuses them on just a few key questions:

> . . . the urgency of having only 2.5 million dollars to get to the end line . . . You have 2.5 million dollars to answer the question. You don't have time to screw around with eight scientific questions that are interesting but not relevant to answering the product development question.

This manager thinks that the tension with scientists over time arises from the scientists' tendency to waste time by working on irrelevant questions. He also thinks that the right questions are clear, and that the passage of clock time focuses attention and effort on the right questions.

*Discovery scientists*, in contrast, understand milestones in drug discovery as coming to a deeper, better understanding of how the drug might work in the body. Creating this understanding requires an extensive process of trial and error learning (West & Nightingale, 2009). So, scientists gauge their progress by achieving what we call 'learning events'. A learning event occurs when scientists learn enough about the pattern of interactions between the disease, chemical compound, and the rest of the human body system to indicate the next thrust of work. Rather than seek clear answers to obvious questions, scientists seek to understand patterns of interactions that give them a sense of readiness for their project – *kairos*. Learning events shift attention from working on separate steps to discovering the patterns among those steps that would constitute the product.

One major milestone is to find a lead compound. However, as this chemist explains, they must understand how the compound interacts with the body, which involves biology and physiology. Finding a lead compound is not just about answering chemistry questions:

> When looking for a lead we are not just looking as a chemist, does it bind, but also we are looking for all the properties that make a compound into a drug such as ADME [i.e., absorption, distribution, metabolism, excretion – biopharmaceutical properties] and also toxicology [i.e., safety]. All the parameters are important. Say this is the lead we were thinking of optimizing. If it has multiple liabilities optimization would be very hard. A compound is a foreign substance so the body tries to eliminate it, metabolize it, or excrete it like food. We have to try and trick the body. This is a fine balance.

Scientists understand the plausibility of lead compounds only if they also understand 'all the parameters' that would reflect how a drug might work in the human body. Discovery scientists have no simple answers to clear questions, so they explore many possibilities.



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Scientists often describe linking up their particular insights with other insights, because all learning events involve understanding patterns, not just learning about a single aspect. For example, a computational chemist explains how his group relies on the structural biology group to generate data for their models:

> We have a structural biology group here that looks at how the molecules or drugs bind to their enzymes or receptors . . . They can look at it in total detail, atom by atom at its binding sites. Using that information we develop models to try and improve the molecules and see if we can modify them to pick up some other interactions . . . It is a constant fusion of many ideas that come from many people with different perspectives. . . .

He emphasizes the 'constant fusion of ideas' across specialty groups to modify the molecules to bind in different ways with enzymes or receptors. Each group depends on others to generate insights so they can learn about the possible pattern. Scientists work more subjectively by working iteratively with each other and with different possible compounds, searching for improvements. If they can enhance a compound's efficacy, but at the same time reduce the compound's safety, the overall pattern would not be improved. Because of these complexities, the effect of modifying one aspect of a compound is likely to have unpredictable consequences. Progress, therefore, can be seen as scientists' reaching a deeper understanding of how the drug might work in the body. Managers, however, might consider these iterative and emergent learning activities to be an undisciplined waste of time.

The scientists are also very aware of the tension with managers over time pacing. For example, one chemist explained that now they must carry out a certain number of activities by a certain time. The result, he said, is that they are less likely to work on something 'from scratch', because they are more likely to find something if they work on something less risky. So scientists work on fixing an existing drug (e.g., making it more selective) and not on searching for new patterns. Scientists working under clock-time pacing focus on drugs that are 'less risky' and are unlikely to uncover new drugs for unmet medical needs. Imposing clock-time pacing on drug project work may be part of the reason for the paucity of new drugs.

Managers and scientists understand the milestones of drug discovery very differently: getting answers versus developing understandings of the plausibility of patterns, respectively. As a result, they understand progress very differently: as completing tasks to produce those answers in a predictable period of time versus achieving unpredictable learning events. Managers push for efficiency and speed, but may ignore the exploratory nature of this complex innovation process. Scientists push for discovering unknown patterns of interactions that may comprise a good drug, but may spend too much time running down blind alleys. Managers do not look for patterns, while scientists do not look for quick answers. These different understandings of progress also lead to very distinct pacing mechanisms that



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coordinate different aspects of drug discovery work in different ways, as we illustrate next.

*Different pacing mechanisms for making progress.* *Strategic managers'* attention and effort are directed by clock-time pacing to reduce uncertainty, decrease the number of questions that are addressed, and decrease the time needed to get answers. These are the day-to-day activities through which innovators make progress, in the minds of strategic managers, and these are the activities that coordinate everyday work. For example, this manager implies that drug discovery work is a linear 'chain' of activities, not a complex learning process. He emphasizes completing functions that add unique value to the information produced:

> R&D productivity first starts with understanding that it is a development chain, not a series of non-integrated functions but rather a series of integrated functions each of which adds a unique type of value to the information that is produced . . . Productivity means the amount of throughput . . . of information related to specific molecules or claims per dollar invested, and also the value of that throughput. To increase R&D productivity means that you need to have more information-generating projects running through per dollar spent . . . This development chain is no more than . . . a series of questions we have to answer as cheaply and quickly as possible, and usually in the same order.

He highlights the integrated nature of the work but emphasizes that each step adds unique value. He also suggests that the functions to be carried out and the questions to be answered are given, so everyday activities comprise generating a greater volume of information per dollar spent. His description suggests ticking off pre-defined activities quickly and cheaply. Coordination among people and tasks automatically occurs through the efficient execution of predefined steps.

Managers are also aware of the tension with scientists over what activities constitute making progress. This manager explains that focusing in on the core questions that will advance the molecule is essential, but says that the scientists want to work on a thousand questions:

> A scientist would say . . . it is going to take all the money in the world to understand this at a level of detail that would satisfy me and so they can list a thousand questions for any one disease or target that are really important questions scientifically to answer. However, only 20 are needed to advance the molecule. It is really a question of how much do you fund to take it to the next – to resolve uncertainty versus how much do you fund to get perfect understanding. You need not have perfect understanding to go to the next step.

He thinks that scientists want to get perfect understanding, and so do not work on the right questions, and do not focus on resolving uncertainty. However, to say that



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there are only 20 questions to answer suggests that there is a clear path to the end goal of discovering a drug.

*Discovery scientists*, in contrast, rely on event-time pacing, which directs their attention and effort to everyday activities that generate learning events in order to make progress. Rather than reduce uncertainty, scientists try to figure out how a compound might behave in the body against the disease, despite the uncertainty. Scientists want to speed up the occurrence of learning events, but they try to do so by integrating more activities earlier in the discovery process, as this team leader explains:

> I think the biggest problem a discovery person and an early development person faces is how can you design your strategic path so that you can make those decisions faster and not spend resources on drugs that are not going anywhere. In discovery you are working in your own shop so you can do that – we bring in toxicity tests early in the program – in early development we could do that by getting it to man as quickly as possible . . .

Rather than speed up separate steps, this team leader seeks to speed up making connections among toxicity tests with other steps early in the process. He says that he can do so because he is 'working in his own shop', and can make his own decisions (in this case, to work with an outside company to do the tests quickly). He also said that the big matrix of departments at his large pharmaceutical company slows down his efforts by, for example, taking eight weeks to carry out a two week test. So, while managers think that scientists work too slowly, scientists think that the managers organize work too slowly.

A number of scientists highlight the core activities of learning. For example, a genomics director explains how they have changed from working on targets separately and handing them off to the next group to staying with targets in an integrated process:

> Many years ago . . . the industry would work on the target, find a drug and throw it to the clinic and then they would go and work on another target. Now we stay with a target for longer and we make our first drug and we know it is probably not going to succeed. And as it tripped up we use the learning from that to recycle and try and make an improved molecule. There are a lot of things like that that we can design, deliver improvements initially, and as things trip up we can go back and design even better improvements. It is based upon the learning.

He stresses their learning by iterating among adjustments and experiments. Note that the event of finding a target emerges over time by learning, and is not accomplished in a single step at a single point in time.



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A technology director at another firm describes similar changes from scaling up separate steps to integrating insights across steps:

> I think what happened in what I would call the genomics era is the discovery piece became somewhat more distant from the development piece. So now . . . we do some early testing to look for what we call drugability. [That] could be some early tox work, some early distribution work. They will dump stuff in with liver enzymes and see if it heavily metabolized, there are some assays up front.

He describes looking for patterns, and notes that trying get tasks done quickly led to scaling up separate steps (e.g., genomics), which instead separated activities. Making progress by focusing on reducing the uncertainty, the questions asked, and the time taken to get answers is very different from making progress by learning about patterns.

*Different pacing mechanisms for assessing progress.* Managers and scientists agree that decision-making is not well done, as explained by this early development scientist:

> Across a lot of the industry about 50% of things that go into Phase III [last and most expensive phase of clinical trials with thousands of subjects] fail and never make it out to a file, and that is a shame. And that is hundreds of millions of dollars, and you should be able to predict better than that by the time you get to Phase III . . . Part of it is figuring out how to use our data and be better at predicting how things are going to go, and I think the other is just making better decisions and not going ahead with things that show marginal effects just for the sake of plowing ahead and keeping the speed on.

However, since managers and scientists make progress differently, they also assess their progress differently. So each group seeks to improve the decision making in very different ways.

*Strategic managers* assess progress by trying to systematically assess the clear answers that, ideally, are generated by how they make progress. This manager explains that a major problem in their decision-making is the failure to get complete, clear information:

> . . . what we strive for is completeness of data where possible, but most importantly transparency, because the thing that will be most disruptive to the decision making is when someone has information and not everyone has information . . . What you find is the data go all over the place because somebody in the room will know that there was a safety signal and somebody else in the room will know that the chemistry is falling apart and another person in the room will have a



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> perception that this is the biggest drug since [company blockbuster]. You are just all over the place . . . Until a few years ago we had a pretty dictatorial style . . . It has really only been under [new R&D VP's] leadership, who wants to be informed when he makes a decision. He wants to know all of his options and all of his choices, importantly he wants to know what the costs and risks are . . . Our decision makers are screaming for this information . . .

She feels that the divergence of opinion among the scientists is disruptive, and this disruption is caused by incomplete information. Until recently, she notes, they relied on a 'dictatorial style' of decision making where the R&D vice president would make all the decisions, so they have limited collective experience with effective decision making. However, decision makers are 'screaming for information', which suggests that managers expect that factual and objective answers to questions should be more readily generated. This same manager emphasizes the need for informed and rigorous decision-making:

> We have to really inform our decisions and so we are trying to get to a point where every decision is made with the best possible and most rigorous data in front of the decision makers, and that includes things like what is it going to cost, what does it do to the capacity, what are your lost opportunities if you pursue this drug rather than that drug . . .

The effort to inform decision-making is certainly reasonable. But the emphasis seems to be on objective facts that she thinks should be more readily available.

*Discovery scientists* assess progress by negotiating inter-subjectively – with one another – to merge individual insights, thoughts, and feelings (Weick, 1995), and to create a 'negotiated order' (cf. Strauss, 1978) for the project. The scientists do not have easily measured or objective criteria in this complex innovation process. So they judge whether or not they have achieved a learning event. This pacing mechanism draws scientists together to negotiate whether they can see a plausible pattern that they think they can manage.

This biology leader describes how they judge whether or not they have identified a good molecule, which is a major learning event. Her comment indicates that assessing the learning events is a subjective process: 'At the point where we say OK I have something that I feel comfortable with, this molecule is something that I really like to work with . . .'. Assessing progress is based on subjective feelings about 'liking' this molecule, and thinking that they can work with it and develop it into a drug that will modify the disease they are going after. There are few objective facts and few clear, complete answers.

Another scientist describes the negotiation over some of the toxicology testing they do, indicating that the arguing among scientists is not disruptive. Rather, that is how they work:



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> All of our drugs have intensive cardiovascular testing before we recommend them forward. Now, it could be possible that the positives in the test could go forward and there are examples of drugs that could go forward and not have any problems in the clinic but . . . it is hard to convince people otherwise . . . There is always controversy around that. You are always asking the questions but that is what drug discovery is. It is constantly going back and forth and arguing, so you have to really enjoy arguing.

As he explains, results of tests are usually not definitive and answers are not clear, so they are always asking questions and constantly 'going back and forth and arguing'. The participants negotiate whether or not they see serious toxicity and so a project should be stopped, or if they can rework the compound to eliminate that toxicity. They do not want to shut down a good drug possibility, but they also do not want to spend hundreds of millions of dollars on clinical trials only to find out that this serious side effect still exists.

The process of negotiating the meaning of the learning event draws people together to coordinate their activities and expertise. Negotiating relies on scientists' practised ability to draw on deep but tacit background knowledge in their fields (Fleming & Sorenson, 2004; Nightingale, 1998). The negotiating is framed by science, as this biologist explains:

> That is what we do. We apply science to science and . . . good data is what makes decisions. Everything in that process is only based on the data, that is it, the data will tell you where to go. Sometimes the data can go in different ways and you have to balance because nothing is predictable . . . There are many different questions that we have to calculate. And if we do this, it is really a good scientific rationale that in the end we are going to answer the right questions and we are going to be successful in modifying a disease . . .

They use their rich tacit background knowledge of science to define the data and the sense they make of it. But the data sometimes 'can go in different ways . . .'. However, as this scientist emphasizes, they do have criteria for decision making, which include having good data, calculating different questions, using a really good scientific rationale, and answering the right questions.

To scientists, assessing progress is using their science to make sense of possibilities, not to provide complete, transparent answers. Another chemist said that in the past, their R&D director emphasized a broader evaluation of a complete therapeutic focus. The scientists appreciated it when the director assessed the quality of their approaches rather than counting the steps taken. He feels that managers focus now on quick answers and on making sure answers are right, not on the more intuitive and emergent process of answering the right questions.



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*Different pacing mechanisms for directing progress.* The third pacing mechanism that differentiates managers and scientists is how people direct progress by determining the next thrust in the work. *Strategic managers* direct progress straightforwardly, by proceeding along a single, presumably optimal, path. Their search for clarity and certainty draws managers' attention and their effort is focused on accomplishing the immediate next steps quickly and cheaply:

> At each step . . . we create more information and you resolve uncertainty. Uncertainty at the beginning is huge and you are sequentially resolving it. Resolving it could mean I have resolved uncertainty it is a loser or I have resolved uncertainty and it continues to look like a winner . . . What are the sources of uncertainty? In what way using new technologies and insights can we reduce that uncertainty sooner and can we pay less to resolve uncertainty . . .

This manager emphasizes reducing uncertainty. He wants to find the right path, but his view of how to go forward is focused on the near term and taking the next step in the process, which cycles back to how managers think that progress is best made: moving sequentially through a given process and successively reducing uncertainties by paying for information.

*Discovery scientists* do not know what the next steps will be until they arrive at a learning event. Learning events direct their progress by providing new questions and new aspects to learn about. Scientists build on learning events to anticipate what the emerging pattern might be, and develop experiments to flesh that out. This team leader describes how he works with others to develop next thrusts in the drug development process, once a key learning event has occurred:

> We work with [the marketing group] and the clinical development people to come up with the disease profile and the target product profile . . . I work on that very early in the discovery process . . . sometimes at the reception of the target but more likely when I have a compound that I say is ready to start looking at the early development process. We call that a contract meeting where we actually go to this early development committee and say here is the new drug, here is the kind of profile that I am going to make around it, here are the tests that I am going to do to show it is safe in cardiovascular, here is the efficacy tests and the drug metabolism profile. When I have done all this I am going to recommend it forward, so give me input now . . .

He anticipates the type of activity the drug will have against a particular disease. He outlines the tests he will use to explore this anticipated but yet to be realized pattern, and invites the marketing and early development groups to contribute to the plan. If the drug profile he seeks emerges from the tests (the next learning event), then he will 'recommend it forward' to early development for more in-depth assessments.



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Rather than move step-by-step along a given path, scientists go forward by fleshing out multiple options. Scientists want to proceed along several paths in parallel by trying out versions of a compound with different properties to learn more about how to optimize that compound, which cycles back to how they make progress by learning. For example, this chemist re-iterates that, for the scientists, to go faster is to learn better:

> To make it go faster – to get the feedback faster and also when you eliminate the white space to getting that backup compound to come forward – certain companies can spend the resources to take two or three compounds in parallel – we need to try and be able to do that more but then again it is resource limited.

To learn better is to work in parallel along several paths. Scientists think that if more options are available, it is more likely that progress can be made. Scientists like to move forward along several paths at once, while managers like to move along a single optimum path. Managers also think that scientists ask too many questions and fail to focus on critical issues.

Figure 1 summarizes this overall discussion by re-iterating the contrasting milestones and three pacing mechanisms from Table 2, and showing how several of the tensions we discuss above work between the two perspectives on time pacing.

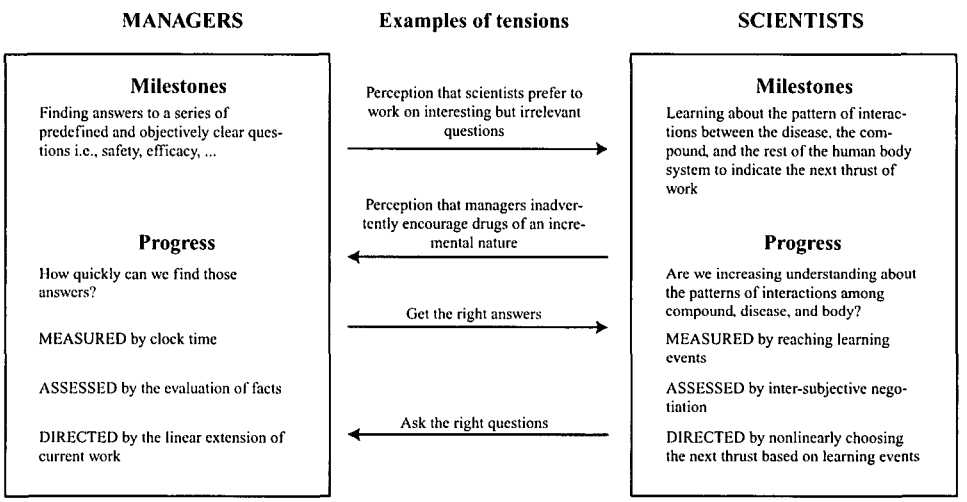


Figure 1. Contrasting milestones and pacing mechanisms between managers and scientists

## How This Tension Negatively Affects Innovation if Clock-time Pacing Dominates

Both clock-time pacing and event-time pacing seem to have an important role to play in orchestrating the very long term and complex process of drug innovation.



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As we have demonstrated, the two pacing mechanisms are two different temporal structures (Orlikowski & Yates, 2002), or mental maps, about time pacing innovation work. The tension arises because clock-time pacing is more familiar and so dominates, stifling the effective use of event-time pacing. We discuss three negative effects of this tension, so that clock-time pacing conflicts with and dominates event-time pacing.

Since managers and scientists focus on different subsets of activities, one negative effect is that the tension fragments inherently interactive activities. Fragmentation means that not all necessary activities will be carried out, and that connections among activities will be overlooked. Fragmentation also leads to a reductionist focus on the parts, which limits the understanding of the mechanisms of action among the parts (Grinnell, 2009). For example, a team leader states:

> When we decide to say yes we will go to GMP [Good Manufacturing Process is a set of U.S. Food and Drug Administration regulated sequence of steps] scale-up of a compound it automatically gets on the dance chart, a timeline of six months – that is our time usually of what it takes – our average time and that is actually a problem because not all projects are going to take six months, some will take nine and some will take two but it is assumed that you have six months there in our projected time . . . It is a thing that as a compound development leader which I have to fight all time.

Perhaps ironically, the team leader wants to move quickly to develop GMP for his project, but managers follow a mechanistic, clock-time process to manage the GMP process, ignoring the immediate needs for learning in the project.

Another negative effect is that clock-time pacing shifts attention and effort to existing solutions and pre-defined problems (Grandori, 2011). Since clear answers or objective facts do not exist in complexity (Weick, 1995), evaluating projects of drug discovery on criteria derived from clock-time pacing can lead to the premature closure of suboptimal possibilities. The next excerpt demonstrates the frustration of a discovery scientist with management's insistence that the discovery process should meet the demands of cycle time:

> While we can get you 10% more widgets in 20% less time doing it the same way we have always done it, if you want a better widget then maybe we need to assess the expectation on cycle time and numbers for a period that will allow us to . . . come up with a better widget . . . I think we are all for efficiencies, but cycle time is potentially a fallacy in our world. It is called research for a reason. If we were building widgets we could get the best and the brightest to figure out how to build the widget faster but we are not. We are building drugs for increasing[ly] complex diseases and targets and you just cannot order that up off of a menu. And you often don't know what the path that you have set will be.



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Third, even though drug development projects take an average of thirteen years, allowing clock-time pacing to dominate event-time pacing leads to a short-sighted view of future innovation activities, inhibiting the ability to recognize long-term future possibilities within and across drug development projects. For example, in comparing the traditional approach of discovering a 'blockbuster' drug to an approach dominated by clock-time pacing, one discovery scientist said:

> The old school says wait, let's fix it, the new school says no to 'fix it now' and if you don't make progress with it stop. If you talk to people who developed blockbusters, they all say there were multiple times when people tried to kill the project.

Simply put, allowing clock-time pacing to dominate leads to a short term focus, and reduces the number of alternatives that are considered. This limited view of the future can blind discovery scientists to emergence, reduce their collective ability to spot patterns, and eliminate new and more promising paths with richer consequences (Gavetti & Levinthal, 2000).

## Overcoming the Tension between Clock-time and Event-time Pacing

In this final section, we speculate on possible ways to overcome these negative effects of the tension between managers and scientists over time pacing, and remove the conflicts we have illustrated. These ideas are speculative because our data do not include clear contrasts between successful and failed drug projects, so we have only a limited view of employing both kinds of pacing, based on what people said they were trying to do to improve innovation. We suggest that event-time pacing is most suited for regulating attention and effort at the project level, while clock-time pacing is most suited for regulating attention and effort at the strategic level, as other researchers suggest (Brown & Eisenhardt, 1997). Rather than impose clock-time pacing on innovation projects, as we find that managers now try to do, we suggest that clock-time pacing be used for managing the flow of strategic resources and building capabilities. To employ both kinds of pacing at the same time, we suggest a common orientation to milestones, progress, and the pacing mechanisms for making, assessing, and directing progress. Each perspective on time pacing identifies different trajectories of events and experiences. If they are used together, rather than treated as mutually exclusive conflicting practices, they can map out more of the future by encompassing more alternatives to be explored more productively.

We propose that the common understanding of milestones and what constitutes progress for projects should be learning about patterns, not getting clear answers or checking off steps. Learning should be in the foreground of everyone's attention and effort, not in the background. Managers should focus on the development of resources and capabilities to support learning more productively within projects, not on micro-managing the projects with clock time. If progress means learning,



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then managers can focus on getting answers to process questions, such as which activities can be done more efficiently to surface patterns, and what are the barriers to learning that can be overcome. Managers can also develop strategic priorities that frame everyday learning, so that certain forward paths may not be explored further while others may be expanded. Managers would use these strategic priorities to set constraints on local action within projects. They would also observe outcomes that arise and tune the system by altering constraints or changing the amount of resources that are provided, as Anderson (1999) recommends for the management of complexity.

The three pacing mechanisms can work together if they are each applied to a different level of the organization. Effective learning at the project level depends on the quality of the learning activities, asking the right questions, interpreting results, and developing promising alternatives with rich and useful consequences, which is enabled by event-time pacing. Effective learning at the strategic level concerns how quickly people explore the interactions and react to results, and surface and challenge assumptions in the light of new information, which is enabled by clock-time pacing. Managers can use clock-time pacing to regulate the development and deployment of resources, so that needed technologies are ready and accessible.

The problem of biased decision-making can be overcome if projects are assessed on how well people understand the patterns for each project, and if they can use those understandings to select a promising next thrust in discovery work. Managers and scientists both need to become better skilled at using inconclusive results to challenge assumptions and interpretations, and to reformulate problems more productively. Managers can use clock-time pacing to develop resources that enable people to reach these negotiated judgments more readily.

Finally, the problem of a short-sighted future perspective can be overcome by using the two different trajectories of events together. The trajectory of learning events for each drug project maps out a variety of paths from the current learning event to a future learning event. But this trajectory can be ephemeral and inarticulate. Clock-time pacing can create the collective ability to be on the lookout for patterns by marshalling resources efficiently, creating new technologies, assessing progress in deploying and using capabilities, and efficiently using learning events to choose next thrusts. These clock-time activities trace out another trajectory of events that can fill in between the unpredictable learning events. In particular, developing alternate business models enables managers to use more drug possibilities, such as those for small markets. Expanded business opportunities open up more paths and possibilities for the future.

## DISCUSSION

This study of the tension between managers and scientists over time pacing strengthens the theory on time, time pacing, and innovation in three ways. First,



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exploring the tension reveals two qualitatively different forms of time pacing for innovation: clock-time pacing, which embodies the dynamics of *chronos*, and event-time pacing, which embodies the dynamics of *kairos* (Garud et al., 2011; Orlikowski & Yates, 2002). Existing research already notes that two different forms of time pacing exist. Our first contribution is to detail the dynamics through which each perspective shapes and guides everyday activities of innovation. Our analysis matches up detailed explications of clock-time pacing that already exist (e.g., Brown & Eisenhardt, 1997) with equally detailed explications of event-time pacing, and along the same dimensions for defining and achieving progress. We provide a much fuller account of how event-time pacing regulates people's attention and effort and coordinates innovation work than do existing studies. We also suggest that event-time pacing can be as systematic as clock-time pacing, since both provide coherent understandings of what constitutes progress.

Detailing two different forms of time pacing expands the ways that time pacing can enable innovation. When progress cannot be scheduled or timed by the clock, as is the case with complex innovation, people can still orchestrate future trajectories of events, anticipate activities that need to be accomplished, and coordinate attention and effort in order to carry out those activities. Event-time pacing can help structure the inherently exploratory searching in complex innovation as we detail in this study. If event-time pacing can be used for coordinating project-level innovation work, then clock-time pacing can be used for coordinating the strategic development and deployment of resources that enable complex innovation, and for new business models that can market the unpredictable outcomes of complex innovation. Clock-time pacing and event-time pacing can be complementary if they are used for their unique purposes. Clock-time pacing helps to constrain the potentially expansive searching of complex innovation and helps to match up resources with possibilities. Event-time pacing helps to constrain the short-term nature of clock time by keeping the future open to emergent possibilities.

However, our second contribution is to suggest that, if left unaddressed, the tension between managers and scientists over time pacing can negatively affect innovation. These negative effects arise because clock-time pacing tends to dominate and is imposed on project work, and event-time pacing remains unexploited. Managers and scientists each deal with the mess of complexity by pushing aside those activities that the other group focuses on. As well, clock-time pacing is much more familiar and taken for granted, so event-time pacing is assumed by managers to be unproductive. The result is that clock-time pacing is applied to project level complex work, and is used as a substitute for event-time pacing, not as a complement. The negative outcomes of this tension are that necessary activities are fragmented, inappropriate criteria are used to assess progress, and the very long, deep future of complex innovation remains unmapped. While a tension per se might be useful, the conflict we find does not seem to be.



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Our third contribution is to suggest some ways to use clock-time pacing and event-time pacing together more effectively, so rather than conflict, both can work in an integrated fashion, and together they can coordinate more of the innovation activities across the organization. We propose that learning about the patterns should be the common understanding of milestones of progress for projects. If everyone has the same common objective of achieving learning events, then different groups can carry out their own innovation activities to support learning events. We also suggest that the three pacing mechanisms for making, assessing, and directing progress can be used in concert. The clock-time pacing mechanisms should be applied to strategic issues, while the event-time mechanisms should be applied to project level issues.

## Limitations

This study has important limitations that restrict conclusions and suggest areas for more research. First, our data do not reflect much about how managers use clock-time pacing for the strategic management of the innovation process overall. We may not have asked enough people enough questions about these possibilities, so more study of the strategic management of complex innovation is necessary. Second, we did not explore how managers can generate rhythm and momentum, for example by introducing new platforms and business models at set times. Research should also examine whether or not science-based event-time pacing generates its own kind of rhythm as some suggest (e.g., Grinnell, 2009), and, if so, whether or not this rhythm can synchronize with a clock-time strategic rhythm. Third, institutional pressures for regular, short term financial reporting on the part of investors, potential partners, and others may continue to emphasize clock-time pacing, so research is needed to explore how event-time pacing can become more legitimate. Fourth, while we provide new details about event-time pacing for complex innovation, more study of learning events and how they can be developed, assessed, and leveraged is needed. Finally, research should examine whether and how event-time pacing might also operate in other kinds of complex and incremental innovation.

## Implications for Chinese Management Research

This study informs Chinese management in three ways. First, pharmaceuticals are a growing sector in China, and Chinese pharmaceutical companies and research centres face the same challenges of aligning dissonant forms of time pacing. Second, complex product innovation is an increasingly important kind of innovation, since new products in many sectors such as health care, alternate energy systems, or new materials involve complexity. Therefore it is important to create a context that encourages event-time pacing and its effective integration with clock-time pacing. Further, the literature suggests that innovation with a high degree



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of novelty might be more challenging in the East, where social norms prioritize usefulness (Mok & Morris, 2010; Simonton & Ting, 2010; Zhou & Su, 2010) and social harmony (Morris & Leung, 2010). In contrast, Western social norms prioritize novelty, and emphasize that individuals should distinguish themselves from others. In the context of innovation, generating highly original or novel solutions is consistent with the novelty and individualistic social norms, while building on existing practices as in incremental innovation is consistent with a collectivist social norm (Herbig & Palumbo, 1996; Morris & Leung, 2010).

Differences in R&D procedures and other contextual elements, rather than differences in personality traits or individuals, support Eastern tendencies towards incremental innovation and Western tendencies toward breakthrough innovation (Morris & Leung, 2010). It is paramount that China develops R&D procedures that can support breakthrough innovation. We suggest that enabling event-time pacing is one requirement to create an environment for breakthrough innovation for complex problems.

The third way that this study informs Chinese management concerns Beijing being on target to hit its extraordinary goal of two million annual patent filings by 2015 (Holland, 2013; Lohr, 2011). The Chinese government introduced incentives for firms (e.g., cash bonuses, and tax breaks) and individuals (i.e., improved housing) to encourage patent filing (Lohr, 2011). Our study suggests that trying to manage science by aiming for a large number of annual patent filings might be at odds with breakthrough discoveries. Reaching two million annual patent filings may focus on filing patents for inventions that have less uncertainty (can be clock-time paced) and therefore are less ambitious (i.e., 'utility patents'). By focusing patent filings on such 'low-hanging-fruit', the Chinese government's well-intended targets may actually reduce 'good science' and fundamental innovation, rather than increase it. It should be noted that China's impressive number of patent filings does not equal the number of patents granted. Worldwide, in 2011, Chinese inventors were awarded 118,000 patents, putting China in third place behind Japan and the U.S. (Holland, 2013). Moreover, China was responsible for huge numbers of filings in established fields like digital communications. Its performance in cutting-edge technologies like solar, wind and geothermal energy patents and fuel-cell patents was weaker. Hence, a more nuanced look shows that, despite the recent increase in patent filings from Chinese inventors, the quality of many applications is actually poor (Holland, 2013). We suggest that the science producing patent filings in China may be clock-time paced, leading to science of an incremental nature.

## CONCLUSION

Before clocks, standard time, railway schedules, and scientific management were invented, people reckoned time with events. Modern management approaches and



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industrial societies developed along with clock-time to manage transportation systems, labour inputs, planning, and production systems. However, innovation did not fit into what became overly mechanical operations systems, so innovators relied on 'skunkworks', venture departments, and renegade 'champions'. These approaches separated innovations from the rest of the organization to protect them. But they did not make organizations systematically innovative, because innovations must integrate with the organization to leverage essential resources, not separate from it. Innovation researchers reached back in time and reworked time management into clock-time pacing, which integrates innovation into the organization. Clock-time pacing reduces cycle time, coordinates diverse activities, and assures that new products are delivered on time and on budget – provided they are incremental efforts that exploit established knowledge. New views of organizing build on clock-time pacing to foster ongoing integration of functions and levels to support innovation.

This study suggests that it is time to reach further back in time to rework time management and organizing, so that complex, science-based innovations can also be integrated into organizations. We propose that complex innovations like new drugs can be paced by event-time pacing, not clock-time pacing. However, organizations, managers, and industrialized societies continue to privilege clock time over event time. It is time to bring back event time and learn how to use unpredictable events to pace ongoing innovation. And since clock-time pacing remains useful, researchers and practitioners need to figure out how to integrate qualitatively different approaches to time management as they also integrate diverse functions and levels to support both incremental and breakthrough innovations. Working with a plurality of time frames may be the next frontier in innovation management, as well as in time management.

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